

Application for
UNITED STATES LETTERS PATENT

Of

YOSHIYUKI KIYA

KUNIHIKO WATANABE

TOSHIKAZU HORII

AND

TAKAO TAKANO

For

DISPLAY DEVICE AND MANUFACTURING METHOD OF THE SAME

DISPLAY DEVICE AND MANUFACTURING METHOD OF THE SAME

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

5 The present invention relates to a display device, and more particularly to a display device and a manufacturing method thereof which enable a normal display by correcting a defective display such as point defects.

DESCRIPTION OF THE RELATED ART

10 A panel type display device such as a liquid crystal display device, an organic EL display device or the like includes a display region which is formed by stacking a plurality of films including an insulation film, a semiconductor film and a conductive film which are formed in a given pattern on an 15 insulation substrate made of glass or the like. Particularly, with respect to an active matrix type display device which arranges a large number of pixels each having a switching element such as a thin film transistor or the like (an active element, hereinafter referred to as a thin film transistor) in a matrix 20 array, in a manufacturing step of the substrate on which the above-mentioned thin film transistors and the like are arranged (a thin film transistor substrate), there arise defects attributed to mixing of foreign substances into films which constitute the thin film transistors, various wirings and 25 various electrodes or to the deformation of pattern and these

defects bring about a defective display.

A defective display (display defect) per pixel unit which occurs on the semiconductor film, the source electrode and the drain electrode which constitute the thin film transistor is 5 referred to as a point defect, while with respect to a defect which causes short-circuiting or connection of lines which supply drive signals to thin film transistors, there may be a case in which a linear or strip-like display defect appears on a screen. The defects which are particularly large in number 10 are point defects (defective lighting) and this defective lighting of the pixel degrades the quality of display images. Conventionally, to cope with the defective display attributed to such defects, processing which enables a normal image display by forming the defective pixel into a black point thus making 15 the defective pixel less apparent, or by applying working (trimming) in which a deviating portion of a connected film or a connecting portion with a film of a neighboring pixel is removed to satisfy the design specification is conducted. However, when the number of the pixels which are formed into 20 the black points is increased, the quality of the display screen as a whole is lowered. When the generated point defect is constituted of short-circuiting of the conductive films, the correction which separates a short-circuited conductive film by irradiating laser beams from an uppermost layer side of 25 various films which are formed in a stacked manner is performed.

Here, as literatures which disclose this type of related art, Japanese Unexamined Patent Publication 2000-347217, Japanese Unexamined Patent Publication Hei11 (1999)-38448 and Japanese Unexamined Patent Publication 2002-82346 can be named.

5

SUMMARY OF THE INVENTION

As the display defect on the active matrix substrate which constitutes the display device, there exist following defects.

For example, a connection defect (also referred to as a short-circuit defect) when semiconductor films which constitute active layers of thin film transistors of neighboring pixels are connected to each other or a pattern defect which deviates from a design specification (a standard deviation defect), a short-circuit defect or a pattern defect between neighboring pixel electrodes, a connection defect (a short-circuit defect) or a pattern defect or an open defect such as a disconnection between neighboring scanning signal lines, between neighboring data signal lines or between a scanning signal line and a data signal line, a connection defect (a short-circuit defect) and an open defect between conductive films such as a connection defect (a short-circuit defect) between a source electrode and a drain electrode of the thin film transistor and the like are named.

When a separation correction, a connection correction and a pattern correction using removal and separation are

performed with respect to these short-circuit defect, open defect and standard deviation defect by irradiating laser beams from an uppermost layer of a plurality of stacked films, there is considered a case in which the film which contains such a 5 defect to be corrected is not positioned as the uppermost layer. In such a case, when the laser beams are irradiated from the uppermost layer, the upper layer films such as a protective film and an insulation film which have no defects are also damaged (receive damages) and are removed and hence, the semiconductor 10 film loses original display characteristics or gives rise to new defects whereby it is difficult to ensure the reliability for a long period. Further, it is difficult to perform the inspection and the correction in a state that a protective film and an insulation film are not provided to an uppermost layer. 15 Even when the inspection and the correction may be performed in a state that the protective film and the insulation film are not provided to an uppermost layer, there exists possibility that foreign substances adhere to the protective film and the insulation film in the course of ensuing formation of the 20 protective film and the insulation film and hence, there still exists a drawback in terms of reliability. Further, the correction based on the formation of black points merely makes the defects less apparent and hence, this correction still fails to provide the normal display.

25 Accordingly, it is an object of the present invention

to provide a display device and a manufacturing method thereof which, even when a protective film, an insulation film or the like is present above a film containing a defect to be corrected, can eliminate the display defect by correcting only the defect 5 of the lower-layer film containing the defect to be corrected without damaging the upper-layer film whereby the reliability of the display device can be enhanced.

The present invention is characterized by performing the correction on a lower-layer film while leaving an upper-layer 10 film as it is at a point of time that a defect is corrected. For example, when a laser is used, a wavelength, an output and an irradiation method of laser beams which are used for the defect correction are optimized. That is, the separation, the connection or trimming of a film to be corrected is realized 15 by irradiating laser beams in optimum conditions for performing the separation, the connection or trimming of only the film to be corrected without damaging the upper-layer film.

Fig. 17 is an explanatory view showing the relationship between a wavelength and absorbance of laser beams for various 20 films formed on a substrate which constitutes a display device in an example where the various films are formed of a semiconductor and an insulation film. Here, an amorphous silicon (a-Si) semiconductor film which constitutes an activated layer of a thin film transistor and an insulation 25 film (a PAS film: SiN here) which is present above the

semiconductor film are used as the example. The wavelength (nm) of the laser beams is taken on an axis of abscissas and absorbance (relative value) is taken on an axis of ordinates in Fig. 17. Laser beams having a wavelength of 250nm to 350nm are absorbed 5 in the a-Si semiconductor film and are hardly absorbed in the insulation film SiN which is present above the a-Si semiconductor film. Also among a metal wiring film, a transparent conductive film and the insulation film, particular absorbance relationships are recognized with respect to these respective 10 films.

Under these facts, the present invention is characterized by adopting following correction methods (A), (B) with respect to the correction of a semiconductor film which constitutes an activated layer of a thin film transistor, for example.

15 (A) In trimming which performs the correction of a connection defect (a short-circuit defect), that is, the separation correction when the semiconductor films are connected to each other between neighboring pixels, laser beams having a wavelength of approximately 250nm to 350nm are 20 irradiated from an insulation film SiN side, and

(B) By irradiating laser pulses of low output to the same portion plural times, damages to layers other than the semiconductor film which are caused by the thermal damage other than the absorbance can be suppressed to a minimum level.

25 Also conventionally, when a trimming range is larger than

a movable range of laser beams or when a shape to be corrected is complicated so that a single irradiation cannot perform the sufficient correction, the laser beam irradiation is performed plural times. However, the present invention differs from the 5 conventional technique with respect to a point that the laser beams are irradiated to the same portion by dividing the laser beams plural times. Further, also with respect to films other than the semiconductor film, for example, conductive films such as scanning signal lines (scanning electrodes), data signal 10 lines or the like or transparent electrodes such as pixel electrodes formed on the substrate, using laser beams having wavelengths and outputs corresponding to absorbance characteristics of the films to be corrected, the laser beams are irradiated to the same position to be corrected by dividing 15 the laser beams a plural times.

Due to such corrections, the damage on films other than the films to be corrected, particularly the damage on the film above the film to be corrected can be minimized and hence, the defective display can be suppressed whereby it is possible to 20 obtain the display device which ensures the reliability for a long period. Further, different from the formation of black points, it is possible to make the display device perform the normal display.

Further, according to the present invention, since the 25 thermal damage at the time of laser beam irradiation can be

suppressed to a minimum level, the induction of other defects and the occurrence of mechanical damage such as the peeling-off of films can be suppressed thus also giving rise to an advantageous effect that the characteristics defects on driving 5 of pixels such as the deterioration of characteristics of thin film transistors attributed to drawing of hydrogen from the semiconductor film are hardly generated. Still further, depending on the layer to be corrected, it is possible to perform the correction such that the semiconductor film receives no 10 damage in appearance in principle.

To explain the representative constitutions of the present invention, they are as follows.

(1) A display device according to the present invention forms a display region where a plurality of films including 15 an insulation film, a semiconductor layer and a conductive film are patterned in a given pattern and are stacked on a substrate, wherein

at a point of time that at least one correction portion out of a correction portion which separates a short-circuit 20 defect, a correction portion which connects an opening defect, a correction portion which removes a standard deviation defect, and a correction portion which separates a standard deviation defect of the pattern is corrected, at least one upper-layer film is present above a film to be corrected at the correction 25 portion and the correction is applied to the film to be corrected

while leaving the upper-layer film as it is.

Further, in the display device according to the present invention, as a modification thereof, the correction of the correction portion is performed by the irradiation of laser beams. Further, the correction of the correction portion is performed by irradiating the laser beams from a side opposite to the substrate. The laser beams are irradiated to the same portion by dividing the laser beams plural times. Further, the upper-layer film above the film to be corrected includes at least either one of an insulation film and a transparent conductive film. Due to the above-mentioned correction of the portions to be corrected, a display of the display region can be performed normally. According to the present invention, these constitutional features can be used in a single form as well as in combination.

(2) A manufacturing method of a display device according to the present invention includes:

a film forming step in which a plurality of films including an insulation film, a semiconductor film and a conductive film are stacked to a substrate; and

a defect portion correcting step in which at least one correction out of a short-circuit defect portion separation correction which separates a short-circuit defect, an open defect portion connection correction which performs a connection of an open defect, a standard deviation defect portion

removal correction which performs a removal of a standard deviation defect, and a standard deviation defect portion separation correction which performs a separation of a standard deviation defect portion generated in the formed film is

5 performed, wherein

at a point of correction time of the defect portion correction step, at least one upper-layer film is present above a film to be corrected at the correction portion and the correction is applied to the film to be corrected while leaving

10 the upper-layer film as it is.

Further, in the manufacturing method of the display device of the present invention, as a modification thereof, the correction is performed by irradiating laser beams. Further, the laser beams are irradiated to the substrate from a side

15 opposite to the substrate. The laser beams are irradiated to the same portion by dividing the laser beams plural times. The number of division is set at least 10 times. An irradiation interval is equal to or more than 0.3 seconds. A wavelength of the laser beams is set to a wavelength which allows the laser

20 beams to be more easily absorbed in the film to be corrected than the upper-layer film. When the film to be corrected is an amorphous silicon semiconductor film, a wavelength of the laser beams is set to 250nm to 360nm and an output of the laser beams is set to $0.02\text{W}/\text{cm}^2$. Here, laser beams to be irradiated

25 to the same portion is irradiated by dividing the laser beams

at least 10 times. The above-mentioned upper-layer film includes at least either one of an insulation film and a transparent conductive film. The semiconductor film is an amorphous semiconductor film and the amorphous semiconductor 5 film is subjected to the separation correction or the removal correction.

An activated layer of a thin film transistor which has a source electrode and a drain electrode is constituted by the semiconductor film and the semiconductor film includes an 10 intrinsic semiconductor film and a contact film formed over the intrinsic semiconductor film, wherein the separation correction of a defect which short-circuits the source electrode and the drain electrode through the contact film is performed by removing the contact film present between the source electrode 15 and the drain electrode together with a portion of the intrinsic semiconductor film.

The conductive film is at least one of a scanning signal line, a video signal line and a pixel electrode, and the separation correction is a correction of a short-circuit defect 20 between the scanning signal lines, a short-circuit defect between the video signal lines, or a short-circuit defect between the pixel electrodes. Here, the pixel electrode is a transparent conductive film. Further, a normal display is performed by these corrections.

25 The present invention can use these constitutional

features in a single form or in combination.

The present invention is basically characterized by separation correction and trimming of the short-circuit defect of the patterned film. However, for example, it is also possible 5 to perform the connection correction of the open defect which connects the portions to be originally connected to each other by melting and fluidizing the conductive film without removing by adjusting an output of the laser beams. In such a manner, according to the present invention, it is possible to largely 10 enhance a manufacturing yield rate and, as a result, the reduction of cost of the display device can be realized. It is needless to say that the display device of the present invention is not limited to the liquid crystal display device 15 and the present invention is applicable to other active matrix type display device such as an organic EL display device.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view of an essential part for explaining a pixel arrangement of a display device according to the present 20 invention;

Fig. 2 is a cross-sectional view taken along a line A-A' in Fig. 1;

Fig. 3 is a plan view similar to Fig. 1 for explaining one example of a short-circuit defect of a semiconductor film 25 which is one of defects of a thin film formed on a thin film

transistor substrate;

Fig. 4 is a schematic view for explaining a short-circuit defect state of the semiconductor film in Fig. 3;

Fig. 5 is an explanatory view of the correction of the 5 defect shown in Fig. 4 according to a manufacturing method of the present invention;

Fig. 6 is a plan view similar to Fig. 1 for explaining one example of a short-circuit defect of a pixel electrode which constitutes one of defects of a thin film formed on a thin film 10 transistor substrate;

Fig. 7 is a cross-sectional view taken along a line B-B' in Fig. 6;

Fig. 8 is a schematic view for explaining a short-circuit defect state of the pixel electrode shown in Fig. 6;

15 Fig. 9 is an explanatory view for explaining the correction of the defect shown in Fig. 8 according to a manufacturing method of the present invention;

Fig. 10 is a plan view similar to Fig. 1 for explaining one example of a short-circuit defect of wiring or an electrode 20 which constitutes one of defects of a thin film formed on the thin film transistor substrate;

Fig. 11 is a schematic view for explaining a short-circuit defect state between video signal lines in Fig. 10;

Fig. 12 is a schematic view for explaining a correction 25 of a defect shown in Fig. 11 according to a manufacturing method

of the present invention;

Fig. 13 is a cross-sectional view for explaining one example of a short-circuit defect of a contact film which constitutes a semiconductor film forming one of defects of a thin film formed on a thin film transistor substrate;

Fig. 14 is a schematic view for explaining the correction of the defect shown in Fig. 13 according to a manufacturing method of the present invention;

Fig. 15 is a schematic view for explaining an open defect of a video signal line on a cross section taken along a line a-a' in Fig. 1;

Fig. 16 is a schematic view for explaining the correction of the open defect shown in Fig. 15 according to the manufacturing method of the present invention; and

Fig. 17 is an explanatory view for explaining the relationship between wavelengths and absorbance of laser beams for various films which are formed on the substrate which constitutes the display device by taking the semiconductor and an insulation film as an example.

20

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention are explained in detail in conjunction with drawings which show embodiments. Here, in the following embodiments, a liquid crystal display device is explained as an example. Fig. 1 is

a plan view of an essential part for explaining a pixel arrangement of a display device according to the present invention and Fig. 2 is a cross-sectional view taken along a line A-A' in Fig. 1. Fig. 1 shows four pixels on a substrate.

5 This substrate is a thin film transistor substrate which includes a thin film transistor TFT for each pixel and a large number of pixels each having the thin film transistor are arranged over a glass substrate SUB. One pixel is constituted of a pixel electrode ITO which is connected to a source electrode SD1 of

10 a thin film transistor TFT formed on a crossing portion between a scanning signal line GL (constituting a gate electrode GT at a portion of the thin film transistor TFT) and a video signal line (date line) DL through a contact hole TH. To explain the structure in a manufacturing process, it is as follows. Symbol

15 SD2 indicates a drain electrode of a thin film transistor TFT. In the embodiments described hereinafter, the explanation is made by mainly focusing on the separation correction of a short-circuit defect and the connection correction of an open defect. The correction of a standard deviation defect is

20 performed by trimming. The correction of the standard deviation defect includes two types of corrections, that is, the removal correction which removes the substantially whole deviating portion and the separation correction which removes a portion (the vicinity of a normal pattern) so as to separate

25 an extra portion. Here, the correction of standard deviation

defect is basically equal to the separation correction of the short-circuit defect with respect to a point that at least a portion is removed.

First of all, a glass substrate SUB having a size of 5 370mm×470mm is cleaned and a metal thin film is formed over the glass substrate SUB by sputtering or the like. Here, a chromium thin film having a thickness of 200nm is formed. This metal thin film is patterned using a photolithography step including coating of a resist and a mask exposure step and an 10 etching step thus forming scanning signal lines (gate lines) GL (also forming gate electrodes GT of the thin film transistors). After removing the resist using the photolithography step and the etching step, a silicon nitride (SiN) thin film having a film thickness of 400nm is formed as gate insulation films GI 15 by a plasma CVD method and, thereafter, an amorphous silicon (a-Si) film ASI (intrinsic semiconductor film) having a thickness of 250nm is formed. To impart conductivity to the a-Si film ASI for connection with source electrodes SD1 and drain electrodes SD2 which are formed in a next step, an amorphous 20 silicon (n+a-Si) film which is doped with phosphorus (P) is formed on the a-Si film ASI as a continuously stacked layer thus forming a contact film SIC having a film thickness of 50nm. The semiconductor film is constituted of the a-Si film ASI and the contact film SIC.

25 Thereafter, a photoresist pattern is formed on the

semiconductor film using a well-known photolithography method, and activated layers (islands) of thin film transistor are formed in semiconductor films by applying forming by a dry etching method which uses sulfur hexafluoride and hydrogen chloride.

5 After removing the resist, as a metal film which becomes the source electrodes SD1 and the drain electrodes SD2, a chromium film having a thickness of 200nm is formed by sputtering. Then, by etching the chromium film using the well-known photolithography method and the etching method, the source 10 electrodes SD1 and the drain electrodes SD2 are formed. Here, the video signal lines DL are also simultaneously formed.

Using the pattern of the source electrodes SD1 and the drain electrode SD2 as a mask, the semiconductor film is etched using a mixed gas of sulfur hexafluoride and hydrogen chloride 15 thus obtaining a film thickness corresponding to a design value 150nm. The resist used for forming the pattern is removed and SiN is formed as a film using a plasma CVD method thus forming a protective film PAS having a thickness of 300nm. The protective film PAS is patterned using well-known 20 photolithography method and etching method thus removing the resist. Next, a transparent conductive film having a thickness of 150nm made of indium oxide and tin oxide is formed using a sputtering method and, thereafter, the pixel electrodes ITO are formed using well-known photolithography method and the 25 etching method. Finally, the thin film transistor substrate

is obtained by removing the resist.

First embodiment

Fig. 3 is a plan view similar to Fig. 1 for explaining one example of a short-circuit defect of a semiconductor film which constitutes one of defects of a thin film formed on a thin film transistor substrate. As shown in Fig. 3, semiconductor films ASI (including also a contact film SIC, this definition being applicable to description hereinafter in the same manner) which constitute thin film transistors of neighboring pixels are connected to each other. The connecting portions are indicated as defects DF1, DF2. These defects are referred to as short-circuit defects. To correct these defective thin film transistors into normal thin film transistors, it is necessary to separate these short-circuit defects. Further, a defect DF3 is a standard deviation defect. A capacitance is generated between an a-Si island and a pixel electrode ITO due to the presence of the defect DF3 thus forming a bright point defect. Accordingly, it is necessary to remove or separate the standard deviation defect.

Fig. 4 is a schematic view for explaining a short-circuit defect state of the semiconductor film shown in Fig. 3. That is, Fig. 4 shows a state in which semiconductor films ASI1, ASI2 which respectively constitute thin film transistors of neighboring pixels which are to be originally separated from each other are connected to each other by a short-circuit defect

DF. An insulation film PAS is formed over the semiconductor films ASI1, ASI2.

Fig. 5 is an explanatory view showing the correction of the defect shown in Fig. 4 according to the manufacturing method 5 of the present invention. To separate the short-circuit defect DF, the laser beams L are irradiated from a side opposite to the substrate SUB, that is, from a position above the insulation film PAS. A wavelength of the laser beams is 266nm and an output of the laser beams is $0.02\text{W}/\text{cm}^2$. The laser beams L are irradiated 10 intermittently such that the laser beams L are irradiated for 5 nanoseconds per one irradiation (also referred to as shot) and the laser beams L are irradiated 10 shots with a shot interval of 0.3 seconds. As a result, as shown in Fig. 5, the short-circuit defect DF is removed while leaving the insulation 15 film PAS formed above the short-circuit defect DF as it is and hence, the semiconductor films ASI1, ASI2 are separated from each other. Here, the correction of the standard deviation defect can be performed in the same manner.

The thin film transistor substrate SUB is cut into a given 20 panel size. In this embodiment, two liquid crystal panels each having a nominal diagonal size of 38cm is obtained. An orientation film is applied to the cut thin film transistor substrate and an orientation control function is provided to the orientation film by the rubbing or the like. On the other 25 hand, a color filter substrate having color filters of

multi-colors and an orientation film having an orientation control function is stacked to the thin film transistor substrate by a sealing member while forming a liquid crystal filling port at a portion of the color filter substrate. Then, a liquid 5 crystal material is filled into a gap defined between both substrates through the liquid crystal filling port and is sealed therein. Drive circuits are mounted on terminals provided to peripheries of the panel thus completing the liquid crystal display device. When a lighting test is performed with respect 10 to the liquid crystal display device manufactured in this manner, it is confirmed that the pixel which has the defect thereof corrected operates in the same manner as the normal pixel.

Here, for investigation, the liquid crystal display device is decomposed and the defect corrected portion of the 15 thin film transistor substrate is observed using a scanning electron microscope. As a result, it is confirmed that the short-circuit defect DF of the semiconductor film ASI which is sandwiched by the gate insulation film GI and the insulation film (protective film) PAS is substantially completely removed 20 or trimmed. Here, to perform the separation of the short-circuit defect, it is unnecessary to remove all extra portion and the separation may be performed by removing only a portion of the extra portion. The same substantially goes for embodiments described hereinafter and hence, the repeated 25 explanation is omitted.

Comparison example 1

For a comparison purpose, laser beams are irradiated to perform a correction of a short-circuit defect of a semiconductor film similar to the above-mentioned short-circuit defect under 5 following conditions. That is, laser beams having a wavelength of 266nm and an output of $0.2\text{W}/\text{cm}^2$ are irradiated by one shot (one shot being 5 nanoseconds). As a result, it is found that although the semiconductor film ASI at the portion to be corrected is separated, an insulation film PAS arranged above 10 the portion to be corrected is also destroyed together. When a liquid crystal display device is assembled using this thin film transistor substrate in the same manner as the above-mentioned embodiment, the portion to be corrected remains as a point defect and hence, the substantial correction is not 15 performed.

Comparison example 2

Further, laser beams are irradiated to perform a correction of a short-circuit defect of a semiconductor film similar to the above-mentioned short-circuit defect under 20 following conditions. That is, laser beams having a wavelength of 266nm and an output of $0.04\text{W}/\text{cm}^2$ are irradiated by five shots (one shot being 5 nanoseconds) at an interval of 0.3 seconds. As a result, it is found that although the semiconductor film ASI at the portion to be corrected is separated, an insulation film PAS arranged above the portion to be corrected is also 25

destroyed together in the same manner as the comparison example

1. When a liquid crystal display device is assembled using
this thin film transistor substrate in the same manner as the
above-mentioned embodiment, the portion to be corrected remains
5 as a point defect and hence, the substantial correction is not
performed.

Comparison example 3

Still further, laser beams are irradiated to perform a
correction of a short-circuit defect of a semiconductor film
10 similar to the above-mentioned short-circuit defect under
following conditions. That is, laser beams having a wavelength
of 532nm and an output of $0.02\text{W}/\text{cm}^2$ are irradiated ten shots
(one shot being 5 nanoseconds) at an interval of 0.3 seconds.
As a result, it is found that the semiconductor film ASI at
15 the portion to be corrected is not sufficiently separated. Here,
it is also found that by increasing the output of the laser
beams or by increasing the number of shots in this wavelength
region, not only the semiconductor film ASI but also a film
above the semiconductor film ASI is also damaged. When a liquid
20 crystal display device is assembled using this thin film
transistor substrate in the same manner as the above-mentioned
embodiment, the portion to be corrected remains as a point defect
and hence, the substantial correction is not performed.

As can be understood from these comparison examples, even
25 when the laser beams having the same total energy as the

above-mentioned embodiment are used by increasing the output of the laser beams and by decreasing the number of shots, the desired correction is not obtained. It is desirable that the output is equal to or less than $0.2W/cm^2$. It is desirable that 5 the number of division of shots is 10 or more. Further, it is found effective to use the laser beams of a wavelength having the high absorbance for the film to be corrected than the film above the film to be corrected. Here, with respect to the shot interval, there exists the possibility that the upper-layer 10 film is destroyed when the shot interval is excessively short and hence, it is desirable that the short interval is 0.3 seconds or more.

Second embodiment

Fig. 6 is a plan view similar to Fig. 1 for explaining 15 one example of a short-circuit defect of a pixel electrode which is one of defects of a thin film formed on a thin film transistor substrate. Here, the thin film transistor substrate shown in Fig. 6 has the layer structure having a protective film (insulation film) PAS as an uppermost layer (a layer below an 20 orientation film since the orientation film is formed after correction). As shown in Fig. 6, pixel electrodes ITO of neighboring pixels are connected. Connecting portions are indicated by DF4 and DF5. These are short-circuit defects and it is necessary to separate these short-circuit defects to obtain 25 normal pixels.

Fig. 7 is a cross-sectional view taken along a line B-B' in Fig. 6. In this thin film transistor substrate, a pixel electrode ITO which constitutes a transparent conductive film is formed as a layer below a protective film PAS. Other 5 constitutions are equal to corresponding constitutions of the above-mentioned embodiment. This embodiment is provided for obtaining a normal pixel by separating short-circuit defects DF4, DF5 shown in Fig. 6.

Fig. 8 is a schematic view for explaining a short-circuit 10 defective state of a pixel electrode in Fig. 6 and shows a state in which pixel electrodes ITO of neighboring pixels which are to be originally separated from each other are connected to each other by short-circuiting. An insulation film PAS is formed over the pixel electrode ITO.

15 Fig. 9 is an explanatory view showing the correction of the defect shown in Fig. 8 according to the manufacturing method of the present invention. To separate the short-circuit defect DF, the laser beams L are irradiated from a side opposite to the substrate SUB, that is, from a position above the insulation 20 film PAS. A wavelength of the laser beams is 355nm and an output of the laser beams is $0.01W/cm^2$. The laser beams L are irradiated intermittently such that the laser beams L are irradiated for 5 nanoseconds per one shot and the laser beams L are irradiated 20 shots with a shot interval of 0.3 seconds. As a result, 25 as shown in Fig. 9, the short-circuit defect DF is removed and

hence, the pixel electrodes ITO1, ITO2 are separated from each other. Since the manufacture of a liquid crystal display device using the thin film transistor substrate in which the defect is corrected in the above-mentioned manner is substantially 5 equal to the manufacture of the liquid crystal display device in the above-mentioned embodiment, the repeated explanation is omitted. Also with respect to the liquid crystal display device of this embodiment, it is confirmed that the short-circuit defect DF is substantially completely removed and trimmed so 10 that the liquid crystal display device can perform the normal operation. Here, even when the pixel electrode is formed of a metal film, it is possible to perform the correction of the short-circuit defect.

Third embodiment

15 As shown in Fig. 7, in a thin film transistor substrate in which a pixel electrode (transparent conductive film) ITO is present between stacked films, to perform the separation correction of the short-circuit correction shown in Fig. 8, the laser beams L having a wavelength of 355nm and an output 20 of $0.04\text{W}/\text{cm}^2$ are irradiated from a side opposite to the substrate SUB (from the protective film PAS side) intermittently such that the laser beams L are irradiated by 10 shots with a shot interval of 0.3 seconds. Although a protective film PAS which constitutes a laser-beam irradiated portion is slightly damaged 25 after the irradiation of the laser beams, as shown in Fig. 9,

the short-circuit defect DF can be sufficiently separated. Since the manufacture of a liquid crystal display device using the thin film transistor substrate is substantially equal to the manufacture of the liquid crystal display device in the 5 above-mentioned embodiment, the repeated explanation is omitted. Also with respect to the liquid crystal display device of this embodiment, it is confirmed that the short-circuit defect DF is substantially completely removed and trimmed so that the liquid crystal display device can perform the normal operation.

10 Fourth embodiment

Fig. 10 is a plan view similar to Fig. 1 for explaining one example of a short-circuit defect of lines or electrodes which constitute one of defects of a thin film formed on a thin film transistor substrate. In this embodiment, a short-circuit 15 defect between metal lines in a stacked film formed in the thin film transistor substrate is corrected. Fig. 10 shows a state in which neighboring scanning signal lines GL1, GL2 which are to be originally separated from each other are connected to each other through a short-circuit defect DF6. Further, Fig. 20 10 shows a state in which neighboring video signal line DL1, DL2 which are to be originally separated from each other are connected to each other through a short-circuit defect DF7. Still further, Fig. 10 shows a short-circuit defect DF8 between a source electrode SD1 and a drain electrode SD2. To 25 short-circuit defects generated between the scanning signal

lines (gate signal lines) GL as well as between the video signal lines (data lines) DL formed on the thin film transistor substrate as shown in Fig. 10, the corrections are applied as follows. Here, the correction of the short-circuit defect 5 between the video signal lines DL is explained as an example.

Fig. 11 is a schematic view for explaining a short-circuit defect state between the video signal lines in Fig. 10 and Fig. 12 is a schematic view for explaining the correction of the defect shown in Fig. 11 using the manufacturing method of the 10 present invention. To separate the short-circuit defect DF7, the laser beams L are irradiated from a side opposite to the substrate SUB, that is, from a position above the insulation film PAS. A wavelength of the laser beams is 532nm and an output of the laser beams is $0.04\text{W}/\text{cm}^2$. The laser beams L are irradiated 15 intermittently such that the laser beams L are irradiated for 5 nanoseconds per one shot and the laser beams L are irradiated 5 shots with a shot interval of 0.3 seconds. As a result, although a slight damage remains on an insulation film PAS formed above the short-circuit defect DF7, as shown in Fig. 12, the 20 short-circuit defect DF7 is removed and hence, the video signal lines DL1, DL2 are separated from each other.

Since the manufacture of a liquid crystal display device using the thin film transistor substrate is substantially equal to the manufacture of the liquid crystal display device in the 25 above-mentioned embodiments, the repeated explanation is

omitted. Also with respect to the liquid crystal display device of this embodiment, it is confirmed that the short-circuit defect is substantially completely removed and trimmed so that the liquid crystal display device can perform the normal operation.

5 Fifth embodiment

Fig. 13 is a cross-sectional view for explaining one example of a short-circuit defect of contact films forming semiconductor films which constitutes one of defects of a thin film formed on a thin film transistor substrate. In this embodiment, a short-circuit defect DF of contact films SIC constituting semiconductor films in stacked films formed over the thin film transistor substrate is corrected. In the drawing, symbol GT indicates a gate electrode. A gate insulation film GI, an a-silicon semiconductor film ASI, contact films SIC, a source electrode SD1 and a drain electrode SD2, an insulation film PAS are stacked over the gate electrode GT in this order. Here, the contact films SIC which are arranged below the source electrode SD1 and the drain electrode SD2 must be originally separated from each other above the gate electrode GT. However, as shown in the drawing, the source electrode SD1 and the drain electrode SD2 are short-circuited through the contact film SIC. This embodiment provides the correction which separates the contact films SIC at such a portion.

Fig. 14 is a schematic view for explaining the correction of the defect shown in Fig. 13 according to the manufacturing

method of the present invention. To separate the short-circuit defect DF, the laser beams L are irradiated from a side opposite to the substrate SUB, that is, from a position above the insulation film PAS. A wavelength of the laser beams is 266nm 5 and an output of the laser beams is 0.02W/cm². The laser beams L are irradiated intermittently such that the laser beams L are irradiated 2 shots with a shot interval of 0.3 seconds. As a result, as shown in Fig. 14, the contact film SIC which constitutes the semiconductor film is completely removed 10 together with a portion of the lower-layer a-silicon semiconductor film ASI and hence, the contact films SIC are completely separated. Here, the gate insulation film GI and the gate electrode GT arranged below the semiconductor film to be corrected receive no damage at all. Further, the 15 insulation film PAS above the removed contact film SIC also receives no damage.

Since the manufacture of a liquid crystal display device using the thin film transistor substrate is substantially equal to the manufacture of the liquid crystal display device in the 20 above-mentioned embodiments, the repeated explanation is omitted. Also with respect to the liquid crystal display device of this embodiment, it is confirmed that the short-circuit defect DF is substantially completely removed and trimmed so that the liquid crystal display device can perform the normal operation.

25 Sixth embodiment

Fig. 15 is a schematic view for explaining an open defect of a video signal line in a cross section taken along a line a-a' in Fig. 1. Fig. 16 is a schematic view for explaining the correction of the open defect shown in Fig. 15 according 5 to the manufacturing method of the present invention. As shown in Fig. 15, at a portion where a scanning signal line GL and a drain line (a video signal line) DL cross each other, the open defect DF is formed in the drain line DL due to a stepped portion of a scanning signal line GL which is arranged below 10 the drain line DL. To correct the open defect DF, laser beams having a wavelength which are hardly absorbed by a protective film (insulation film) PAS and are absorbed by the drain line DL are irradiated to melt and fluidize a metal film which constitutes the drain line DL so as to restore the connection. 15

A wavelength of the laser beams used in this embodiment is 250nm to 360nm and an output of the laser beams is $0.02W/cm^2$ or less. The laser beams L are irradiated intermittently such that the laser beams L are irradiated 10 shots or more with a shot interval of 0.3 seconds or more. Since free-alkali glass 20 used as a material of the substrate SUB is known as the material which absorbs this wavelength, the laser beams are intermittently irradiated from the protective film PAS side as shown in Fig. 16.

The connection correction of the open defect has other 25 various application examples. To explain specific examples,

they are as follows.

- (a) the connection between the pixel electrodes made of a transparent conductive film or a metal layer
- (b) the connection between scanning signal lines made of a metal layer or between video signal lines made of a metal layer
- (c) the connection between lines made of a metal layer or a transparent conductive film
- (d) the connection between a line made of a metal layer and a line made of a transparent conductive film
- (e) the connection between electrodes made of a metal layer
- (f) the connection between a source electrode made of a metal layer and a pixel electrode made of a transparent conductive film or a metal layer
- (g) the connection between a scanning signal line, a video signal line or a line made of a metal layer and a terminal made of a transparent conductive film
- (h) the connection between a line made of a transparent conductive film and a terminal made of a transparent conductive film
- (i) the connection between a scanning signal line, a video signal line or a line made of a metal layer and a terminal made of metal
- (j) the connection between a line made of a transparent conductive film and a terminal made of metal
- (k) the connection between a scanning signal line or a video

signal line made of a metal layer and a line made of metal
(1) the connection between a scanning signal line or a video
signal line made of a metal layer and a line made of a transparent
conductive film

5 The application examples are not limited to the
above-mentioned specific examples and, according to the present
invention, it is possible to perform the connection correction
of the open defect of at least one of the scanning signal line,
the video signal line, the pixel electrode, the wiring and the
10 electrode.

Further, according to the present invention, it is
possible to perform the connection correction of the open defect
between two elements selected from a group consisting of the
scanning signal line, the video signal line, the pixel electrode,
15 the wiring, the electrode and the terminal.

Further, also with respect to the separation correction
of the short-circuit defect, the removal correction of the
standard deviation defect and the separation correction of the
standard deviation defect, the present invention is not limited
20 to the above-mentioned embodiments and is applicable to the
semiconductor film, the insulation film and the conductive film
in various portions (formed of either a metal film or a
transparent conductive film, for example,).

Further, also with respect to the film arranged above
25 the film to be corrected, such a film is not limited to an

insulation film (a protective film) and may be a transparent conductive film or the like.

As has been explained heretofore, according to the present invention, even when the protective film, the insulation film 5 or the like is present above the film to be corrected, it is possible to provide the display device and the manufacturing method thereof which can eliminate the defective display by correcting only the defect of the film to be corrected below the upper-layer film without damaging the upper-layer film thus 10 enhancing the reliability of the display device and the manufacturing method.